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RESEARCH ARTICLE

Spondylolysis in ancient Nubian skeletal populations

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Abstract

A comprehensive study of spinal health in ancient Nubia has not been achieved to date. This study is a component of a larger survey of spinal health. It presents a comparative analysis of spondylolysis, with the aim of providing an insight into the quality of life, environmental and socio-political stresses faced by individuals in ancient Nubia. This study provides bioarchaeological data from 515 adult individuals with preserved lumbar vertebrae (where spondylolysis is most commonly observed) from five populations that date from the Meroitic to the Medieval period (350 BC–1500 AD). Contextual data from settlements and cemeteries were used to interpret the data. The results demonstrated an overall crude prevalence of 6.6% for spondylolysis (individuals affected with vertebrae preserved) and an overall true prevalence of 1.2% (number of lumbar vertebrae affected). The data also revealed a number of possible trends, for example, that males were most affected, that there was an increase in prevalence over time, with the highest prevalence rates observed in the Medieval period, and that there was a higher prevalence rate among the populations from Mis Island compared with the other populations. It is possible that activities such as farming, building or rowing as well as socio-political changes could have contributed to the prevalence of spondylolysis seen in this study.

KEYWORDS
ancient Nubia, paleopathology, spinal pathology, spondylolysis

1 | INTRODUCTION

Spondylolysis is a fracture through the pars interarticularis of the neural arch of vertebrae, which leads to the neural arch being separated from the vertebral body; it is mostly found in the lumbar region, usually at the L5 level (Figure 1) (Berger & Doyle, 2019). Clinical evidence has suggested that one key cause of spondylolysis is repetitive stress leading to trauma (Mansfield & Wroten, 2021), but that inherited risk factors, such as vertebral morphology and weakness at the fracture site, may influence its development. However, it is generally accepted that the etiology of spondylolysis is multifactorial, involving a congenital weakness of the pars interarticularis that results in a fracture caused by repeated stress (Figure 1).

Spondylolysis is commonly reported in both clinical (e.g., Chellathurai et al., 2018; Leone et al., 2011; Mansfield & Wroten, 2021) and bioarchaeological literature (e.g., D'Angelo del Campo et al., 2017; Plomp et al., 2012; Ponce, 2010), with a past prevalence of between 3% and 54% (Merbs, 1983; Simper, 1986) and between 3% and 12.5% in living populations (Chellatharai et al., 2018; Eisenstein, 1978). However, prevalence can be higher in athletes, such as gymnasts and wrestlers, in some cases reaching up to 60% (Iwamoto et al., 2004; Sairyo et al., 2011; Tezuka et al., 2017). The high prevalence observed in athletes supports the view that there is a relationship between increased stress placed on vertebrae and the development of spondylolysis (Mansfield & Wroten, 2021).

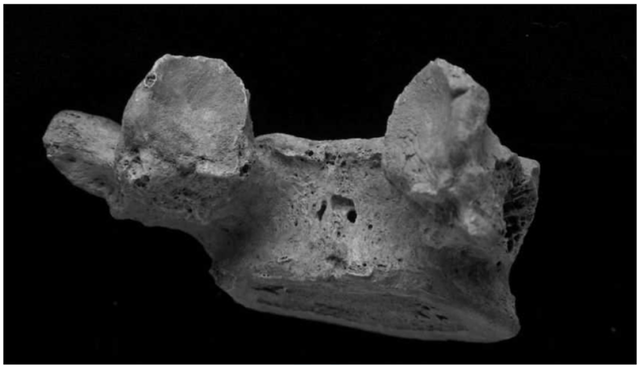

FIGURE 1 Example of complete L5 bilateral spondylolysis. (Mis Island SK1137, photo by first author).

In clinical studies, spondylolysis is observed in both males and females, but males are generally two or three times more affected (Mansfield & Wroten, 2021). This has also been observed in bioarchaeological studies (e.g., Fibiger & Knüsel, 2005; Simper, 1986; Stewart, 1931); for example, Mays (2006) studied the prevalence of spondylolysis in adults from a rural English Medieval population and observed a 14.5% rate for males and 8.9% for females. This was attributed to an agricultural lifestyle involving constant standing and heavy repetitive loading of the spine, with males carrying out more strenuous or manual physical activity.

Today, spondylolysis is observed in both children and adults, with a higher percentage observed in young to middle aged adults. It is not age dependent, and a number of clinical studies have not observed a difference between age groups (Kalichman et al., 2009; Mansfield & Wroten, 2021). In clinical studies, spondylolysis is most commonly observed in the L5 vertebra, followed by the L4 (Mansfield & Wroten, 2021; Syrmou et al., 2010). The same trend is seen in archaeological studies, with L5 being the most affected (e.g., Simper, 1986; Mays, 2006; Binder, 2014: 239). Variation in spondylolysis prevalence rates from different archaeological sites demonstrates regional differences and possibly differences in activities linked to people's lifestyles, but the lack of standardization in the collection and reporting of data in both archaeological and clinical studies must be taken into account when doing comparative work (Fibiger & Knüsel, 2005; Tipper, 2020). This all said, there is a lack of information on the presence of spondylolysis in Sudan from both clinical and bioarchaeological standpoints, and it was the aim of this research to help fill this gap in bioarchaeological knowledge and to explore whether environmental and/or sociopolitical factors had an impact on the spinal health of individuals living in ancient Nubia.

2 | MATERIALS

Ancient Nubia extended along both sides of the Nile River from the first cataract at Aswan to the sixth cataract just north of Khartoum and was divided between what is today the modern countries of Egypt and Sudan. The different regions of Sudan are divided by a series of rapids, the result of the river cutting through outcrops of granite geology, called cataracts, which serve as regional boundaries (Edwards, 2007). The sites for this study were chosen from five different geographical locations across ancient Nubia, ranging from the 1st to the 6th Cataract. This selection provided the opportunity to undertake a detailed temporally and geographically-based comparative analysis of these Nubian populations (Figure 2). All sites were rural farming communities apart from Soba East, which was an urban settlement (Reisner et al., 1910; Žabkar & Žabkar, 1982; Ginns, 2007; Edwards, 1998; Filer, 1998).

A total of 515 adult skeletons dating from the Meroitic to Medieval periods (350 BC–1500 AD) were included in the study, including 237 females and 278 males. A total of 2939 lumbar vertebrae were analyzed. A breakdown of the skeletal assemblages used is provided in Table 1.

El-Hesa was located immediately south of the 1st Cataract on a large island in what is now the area of Shellal. As part of the first Archaeological Survey of Nubia in 1907, and as a result of the enlarging of the Aswan Dam, three Medieval cemeteries were excavated at El-Hesa (Reisner et al., 1910). Sixty adult individuals with preserved lumbar vertebrae were included in this study from Cemetery 2, located on the northeast corner of the island, which is now under water (Edwards, 2004:4). The assemblage is currently curated at the Duckworth Laboratory at the University of Cambridge, UK.

Semna South was located on the west bank of the Nile between the 2nd and Dal cataracts, in the Batn el Hajar (belly of rock) region (Zabkar & Zabkar, 1982). This area is very harsh and inhospitable, comprising rocky ridges and channels and steep banks, all reflecting the narrow Nile valley; it also has minimal rainfall and very poor agricultural potential (Adams, 1977: 24). The site comprised a Medieval fortress and a large Meroitic cemetery north of the fort, for which no associated settlement was located (Zabkar & Zabkar, 1982). It was excavated between 1966 and 1969 by the Oriental Institute Expedition for the University of Chicago (Zabkar & Zabkar, 1982). A total of 560 graves were found, with a total of 592 individuals identified, of which 192 individuals with preserved lumbar vertebrae from the site were included in this study (Zabkar & Zabkar, 1982). The assemblage is currently curated at Arizona State University, Tempe, USA.

Mis Island was located on an island in the 4th cataract. It was excavated between 2005 and 2007 as part of the Merowe Dam Archaeological Salvage Project by the Department of Ancient Egypt and Sudan at the British Museum and the Sudan Archaeological Research Society. The concession area (land allocated to foreign archaeological missions) consisted of about 40 km of the left bank of the Nile, as well as a number of large islands, starting from the fortress at Suweigi West (Dar el-Arab) upstream to Jebel Musa at Kirbekan. The concession area was planned for inundation (Welsby, 2006), and Mis Island is now submerged. A total of 157 individuals with preserved lumbar vertebrae from two Medieval cemeteries identified as 3-J-10 and 3-J-11 were included in this study. The collection is currently on loan from the British Museum, London to Michigan State University, East Lansing, USA.

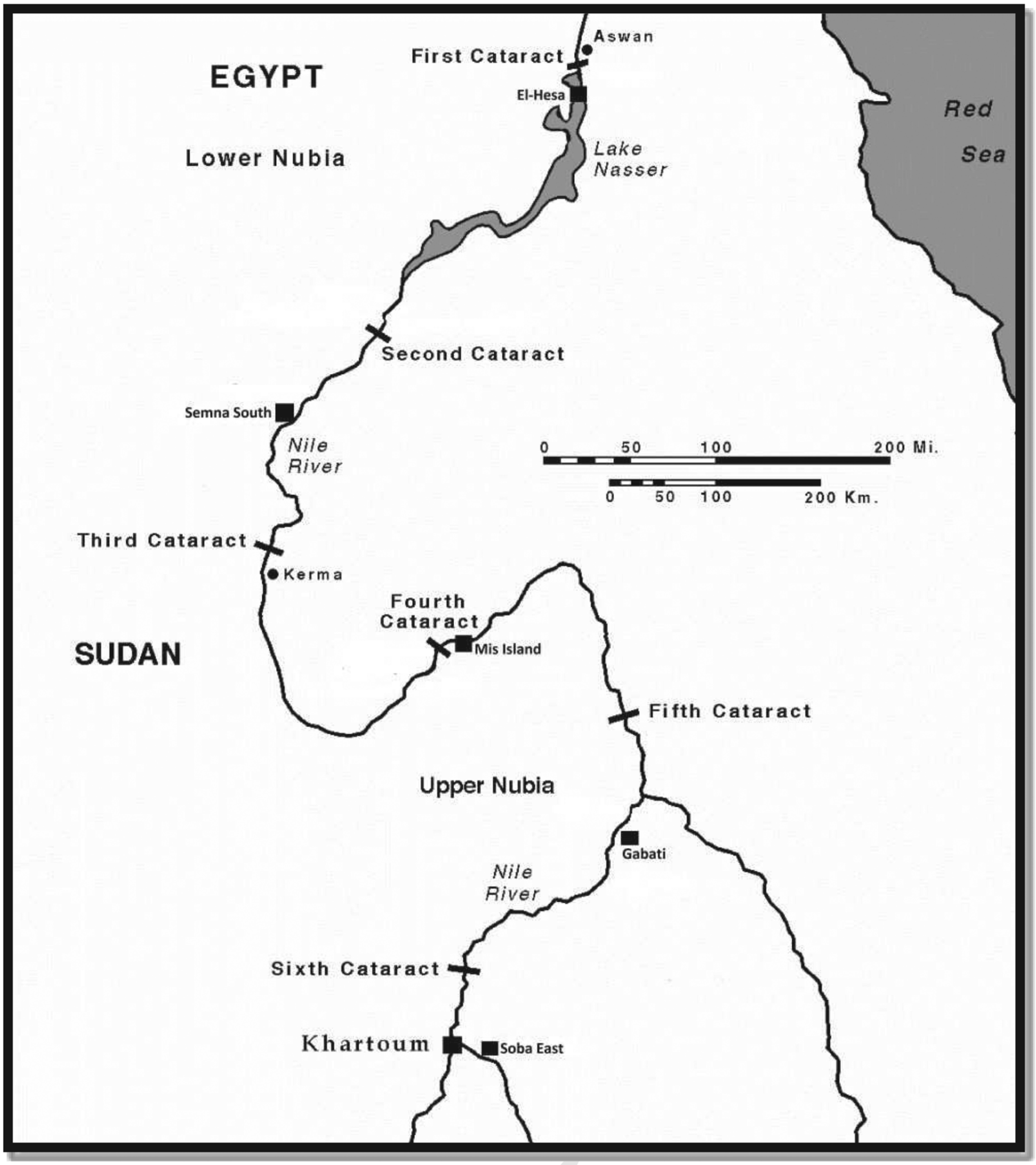

FIGURE 2 Map of Ancient Nubia (adapted from Oriental Institute Sudan Site Map), with the location of the five skeletal assemblages used in this study.

Gabati, a rural agricultural community, was located north of Khartoum, at the northern end of the Aliab basin, which is one of the many large flat agricultural basins along the Shendi-Atbara Reach of the Nile (Edwards, 1998). Located on the east bank of the Nile River between the 5th and 6th cataracts, it is about 40 km north of the ancient royal capital of Meroe and 260 km from Khartoum. The site was excavated in 1994 by David Edwards, and 104 graves were identified, dating from the Meroitic to the Medieval periods. A total of 80 adult individuals with preserved lumbar vertebrae were used in this study. The assemblage is currently curated at the British Museum, London, UK.

Soba East was located on the east bank of the Blue Nile River, a tributary of the Nile River, below the 6th cataract and about 22 km southeast of the modern city of Khartoum (Welsby, 1983). In 1981, the British Institute of Eastern Africa began excavations, and 66 individuals were identified for study on site (Filer, 1998), but the remains of only 39 adult individuals were transported to the British Museum in London for further analysis, where they are currently curated. The remains were not well preserved, and a total of only 26 individuals with preserved lumbar vertebrae could be included in this study.

3 | METHODS

Ethical approval for this research was obtained through the Durham University before the analysis took place. In the wider spinal health study (Tipper, 2020), the recording and analysis standards used for specific pathological conditions and metrical data are derived from

TABLE 1 The sites studied (Ginns, 2007; Welsby & Daniels., 1991; Welsh, 2013).

Site name	Site location	Time period*	Geography	Number of adults	Females	Males
El-Hesa	1st Cataract	Medieval	Granite bedrock and sandstone hills. Narrow Nile channel. Arid zone.	60	20	40
Semna South	2nd Cataract	Meroitic to Medieval	Pre-Cambrian sedimentary rock, later layers of igneous rocks surmounted by small deposits of fertile alluvium. Arid zone.	192	85	107
Mis Island	4th Cataract	Medieval	Granite bedrock covered in sediment. Seasonal flooding. Arid Zone.	157	79	78
Gabati	5th Cataract	Meroitic to Medieval	Flat, fertile land. Seasonal flooding. Border between Arid/Rainfall Zone	80	43	37
Soba East	6th Cataract	Medieval	Flat, fertile soil, large area of cultivated land. Rainfall zone.	26	10	16

*Meroitic (350 BC–AD 350), Medieval (500–1500 AD).

TABLE 2 Adult age categories (adapted from Buikstra & Ubelaker, 1994, p. 26; Brickley & McKinley, 2004, pp. 18–20).

Age category	Age range
Young adult	20–35 years
Middle adult	35–50 years
Old adult	50+ years

FIGURE 3 Young female from Mis Island (SK1161) with complete bilateral spondylolysis of the L5 (Credit: first author).

FIGURE 4 Young adult female with unilateral spondylolysis of the L5 (WFN10510) (Credit: York Osteoarchaeology).

chapters within Brickley and McKinley (2004), Mitchell and Brickley (2017), and Buikstra and Ubelaker (1994). These methods were chosen to ensure standard accepted methods were used, such that the data collected in this study could be used for comparative studies in the future.

Specifically, standard osteological methods were used to estimate the sex and age at death (Table 2) of the individuals using morphological traits of the skull and pelvis (Buikstra & Ubelaker, 1994, Chapter 3; O'Connell, 2004; Brickley & McKinley, 2004). Individuals were categorized as “male”, “probable male”, “indeterminate”, “female”, or “probable female”. Probable males and females were pooled with the definite male and female individuals. Because of the large number of individuals analyzed where sex could be estimated and because of the time limitations on data gathering, “indeterminate” individuals were not included in the analysis. In the case of the individuals from Semna South, sex estimations provided by the excavators on site were initially used and verified using the standard methods referenced above, where possible, as well as with metrical analysis according to Bass (1995). This was because the majority of the pelvic bones from these individuals were not transported to the United States from Sudan and thus were unavailable for examination.

All preserved lumbar vertebrae (L1–L5) for each individual selected for this study were observed macroscopically, and spondylolysis was recorded as present if at least one side of the pars interarticularis showed evidence of separation. Separation was also recorded as either bilateral (Figure 3) or unilateral (Figure 4) complete or incomplete (Merbs, 2002). True prevalence rate (TPR) was defined as the number of lumbar vertebrae affected out of the number of lumbar vertebrae available for study. The crude prevalence rate (CPR) was defined as the number of individuals affected out of the number of individuals in the study. TPR and CPR for spondylolysis were initially calculated for each lumbar vertebra for all five Nubian populations. Next, intra- and inter-group comparisons were conducted according to sex, age at death, and time period, and Chi-squared tests carried out in Microsoft Excel were used to identify any statistically significant differences.

4 | RESULTS

The overall TPR for spondylolysis was 1.2% (36/2939) of vertebrae affected (L1 to L5) and the overall CPR was 6.6% of individuals affected (34/515). Individuals from Mis Island had the highest true prevalence of spondylolysis at 1.6% (15/928) followed by El-Hesa, Semna South, and Gabati all at 1.1%. The same was found for CPRs, with individuals from Mis Island where 8.9% (14/157) are most affected, followed by El-Hesa at 6.7% (4/60). No evidence of spondylolysis were observed for the individuals from Soba East. A significant difference was found between the populations ($X^2 = 810.325$ [df = 1] $p < 0.001$).

Overall, there was a higher number of males affected for both true (1.3%; 20/1580) and crude prevalence (6.8%; 19/278). There was slightly lower TPR and CPR for females compared with males (Table 3), but no significant difference was found ($X^2 = 0.048$ [df = 1] p = 0.826).

Spondylolysis was observed in all age groups, with the most affected being young and middle-aged individuals; old individuals were least affected (Table 4). TPRs by age were again highest in the young age category, 1.6% (17/1095), followed by the middle age category, 1.2% (16/1303). For CPRs, more individuals were affected in the middle age category at 7.4% (17/229), followed by the young age category at 7.3% (14/191). The old age category was least affected 3.2% (3/95), and there was no significant difference observed between the age categories ($X^2 = 2.981$ [df = 1] p = 0.084).

When CPRs were analyzed by sex and age, spondylolysis was observed most amongst young males (9%; 9/100), followed by middle-aged females (6.3%; 6/96). The least affected were the older

TABLE 3 True and crude prevalence rates for spondylolysis by population and sex.

	Female						Male					
	N	*n*	%	*N*[a]	*n*[b]	%	*N*	*n*	%	*N*[a]	*n*[b]	%
El-Hesa	20	0	0.0	119	0	0.0	40	4	10.0	237	4	1.7
Semna South	85	7	8.2	473	8	1.7	107	4	3.7	591	4	0.7
Mis Island	79	5	6.3	468	5	1.1	78	9	11.5	460	10	2.2
Gabati	43	3	7.0	246	3	1.2	37	2	5.4	209	2	1.0
Soba East	10	0	0.0	54	0	0.0	16	0	0	82	0	0.0
TOTAL	237	15	6.3	1360	16	1.2	278	19	6.8	1580	20	1.3

Note: N is the total number of individuals available for study. n is the number of individuals who were affected.
[a]Number of vertebrae preserved.
[b]Number of affected vertebrae.

TABLE 4 True and crude prevalence rates for spondylolysis by population and age at death.

	Young						Middle						Old					
	N	*n*	%	*N*[a]	*n*[b]	%	*N*	*n*	%	*N*[a]	*n*[b]	%	*N*	*n*	%	*N*[a]	*n*[b]	%
El-Hesa	27	2	7.4	158	2	1.3	25	1	4.0	150	1	0.7	8	1	12.5	48	1	2.1
Semna	60	2	3.3	340	5	1.5	91	7	7.7	498	6	1.2	41	2	4.9	226	2	0.9
Mis Island	46	7	15.2	271	7	2.6	71	7	9.9	422	7	1.7	40	0	0.0	235	0	0.0
Gabati	48	3	6.3	272	3	1.1	28	2	7.1	159	2	1.3	4	0	0.0	24	0	0.0
Soba East	10	0	0.0	54	0	0.0	14	0	0.0	74	0	0.0	2	0	0.0	8	0	0.0
TOTAL	191	14	7.3	1095	17	1.6	229	17	7.4	1303	16	1.2	95	3	3.2	541	3	0.6

Note: N is the total number of individuals available for study. n is the number of individuals who were affected.
[a]Number of vertebrae preserved.
[b]Number of affected vertebrae.

TABLE 5 True and crude prevalence rates for spondylolysis by population and time period.

	Meroitic						Post Meroitic						Medieval					
	N	n	%	N[a]	n[b]	%	N	n	%	N[a]	n[b]	%	N	n	%	N[a]	n[b]	%
El-Hesa	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	60	4	6.7	356	4	1.1
Semna South	159	8	5.0	893	9	1.0	24	3	12.5	120	3	2.5	9	0	0.0	51	0	0.0
Mis Island	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	157	14	8.3	928	15	1.6
Gabati	45	3	6.7	248	3	1.2	23	0	0.0	136	0	0.0	12	2	16.7	71	2	2.8
Soba East	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	26	0	0.0	136	0	0.0
TOTAL	204	11	5.4	1141	12	1.1	47	3	6.4	256	3	1.2	264	20	7.6	1542	21	1.4

Note: N is the total number of individuals available for study. n is the number of individuals who were affected.
[a]Number of vertebrae preserved.
[b]Number of affected vertebrae.

males (2.2%; 1/45) and females (6%; 3/50). A higher number of young males (25%; 6/24) from Mis Island were affected than any other age group or population. The Mis Island site also revealed the highest number of affected individuals in the middle age group (males and females combined). Females from Gabati had the highest number of affected young adult individuals (11.5%; 3/26), while Semna South had the highest number of affected old individuals (10.5%; 2/19).

Data on TPR and CPR revealed an increase in both from the Meroitic to the Medieval period (Table 5), although no significant difference was found between the time periods ($X^2 = 0.446$ [df = 1] p = 0.503).

L5 was the most common vertebra affected by spondylolysis (78%, 28/36), followed by L4 (16.7%; 6/36). Only one vertebra was affected at L2 and one at L3, while no cases of spondylolysis was observed at L1. Thirty-four of the 36 affected vertebrae (94.4%) had bilateral spondylolysis, compared with only two (5.6%) with a unilateral break, both of which were affected on their right sides. Only two individuals had multiple vertebrae affected by spondylolysis, one middle aged female from Semna South and one young male from Mis Island. Both individuals were affected in their L4 and L5 vertebrae. There was no evidence of incomplete separation of the pars interarticularis.

5 | DISCUSSION

In this study, the L5 was most frequently affected, with spondylolysis observed in a total of 36/2939 lumbar vertebrae (1.2%) and in 34/515 individuals (6.6%). This CPR figure falls between the 3%–8% frequency range for spondylolysis recorded in living populations (Leone et al., 2011; Mansfield & Wroten, 2021). When compared with studies on past and present African populations in Table 6, the frequencies from this study were higher overall, apart from the study of the skeletons from the 19th century mine workers from South Africa (Van der Merwe et al., 2010). This high rate could be due to high levels of strenuous physical labor in this group. In both clinical (Leone et al., 2011; Mansfield & Wroten, 2021) and bioarchaeological studies (D'Angelo del Campo et al., 2017; Fibiger & Knüsel, 2005; Merbs, 2001), spondylolysis was more common among males than females (as in this study) and possibly a result of higher levels of strenuous activities compared with females. A number of clinical studies have also found that spondylolysis was more prevalent in young and middle-aged individuals (Berger & Doyle, 2019; Mansfield & Wroten, 2021), and again, the same was observed in this study, although there was no statistical significance. This could possibly be due to these age groups representing people of "working age," that is, individuals who were more physically active, such as young and middle aged adults (Fibiger & Knüsel, 2005; Kim, 2018). It is also possible that spondylolysis healed over time and was not as observable in some older individuals.

When the data were analyzed by time period, the highest prevalence rate was found in the Medieval period (although there was no statistical significance), possibly due to an increase in environmental changes and political pressure during this period compared with the previous Meroitic period. Political stability began to deteriorate during the Post Meroitic and Medieval periods in ancient Nubia (Monneret de Villard, 1938; Welsby, 2002: 68), with increased violent confrontations between Egyptian Muslims and the Arab desert groups, impacting trade and resources available to farmers. Deteriorating climatic conditions and aridification that increased over time (Gatto & Zerboni, 2015) could also have had an impact on the ability to cultivate land: less rainfall, less fertile land, and more arable weeds (Development, 2015), especially in the areas with already harsh environments and underlying geology. A study on respiratory disease in people buried in Medieval sites from the 4th cataract in ancient Nubia, (Davies Barrett et al., 2021, 2018) observed high levels of maxillary sinusitis, possibly indicating that the populations were exposed to particulate pollution (sand and dust), supporting the view that environmental factors were impacting the health of people living in ancient Nubia at this time. These two factors possibly resulted in an increase in the amount of labor required to work the land, as well as the intensification of agriculture (Binder, 2014; Davies-Barrett et al., 2018: 143).

By contextualizing the archaeological data for the sites studied, as well as utilizing modern clinical data, a number of possible hazards that are operating for both past and present-day populations in Sudan

TABLE 6 Prevalence rates of spondylolysis from some previous studies (adapted from Tipper, 2020).

Study	Time period	Geographical location	Crude %	True %
This study	350 BC–1500 AD	Nubia	6.6% (34/515)	1.2% (36/2939)
Modern Africa				
Eisenstein (1978)	Modern	South Africa	3.5%	
Allbrook (1955)	Modern	East Africa	4.8%	
Van der Merwe et al. (2010)	1800s AD	South Africa (mine workers)	8.50% (7/82)	
Kyei et al. (2015)	Modern	Ghana, West Africa	18.7% (44/540)	
Ancient Africa				
Dabbs et al. (2015)	1300–1070 BC	Amarna, Egypt	10.9%	
Malnasi (2010)	2650–2200 BC	Dayr Al-Barsha, Egypt	2.3%	
Hussien et al. (2009)	332–30 BC	Bahriyah Oasis, Egypt		1.9% (5/256)
Kozieradzka-Ogunmakin (2020)	AD 90–350	4th cataract, Sudan	11.8% (2/16)	
Americas				
Merbs (2001)	Prehistoric	New Mexico, USA	13% (64/491)	
Pilloud and Canzonieri (2014)	1230–1400 AD	California, USA	17.4% (8/46)	
Weiss (2009)	2180–250 BP (before European contact)	San Francisco Bay, USA	16.4% (24/146)	
Merbs (1996)	1500–1600 AD	Hudson Bay, Canada	12.7%	
Stewart (1931)	ND	Alaska, USA	48.9% (44/90)	
Merbs (2002)	AD 1000–1900	Canada	21.6% (90/417)	
Ponce (2010)	2900–1000 BC	Chile, South America	10.2% (15/147)	2.3% (16/682)
Pacific				
Arriaza (1997)	1200–1521 AD	Tumon Bay, Guam, Micronesia	21% (8/38)	
Europe				
Simper (1986)	1100 AD and earlier	Greenland	54.3% (26/46)	
Mays (2006)	1100–1400 AD	Wharram Percy, UK	11.9% (24/201)	
		Wharram Percy, UK	45.8% (11/24)	
Fibiger and Knüsel (2005)	1200–1520 AD	Chichester, UK	5.2% (16/257)	
Jiménez-Brobeil et al. (2010)	1800–1300 BC	Spain (Agar population)	3.2% (1/32)	
Soler and Calderon (2000)	Modern	Athletes, Spain	8%	

Note: Number of vertebrae studied. Not all information is available for all studies.
Abbreviations: Crude, prevalence rate according to individuals affected with preserved spines; True, prevalence rate compared with the total.

can be identified. These include building, contact with animals such as cattle, horses or camels, general agricultural activity, travelling by boat (rowing) between island communities and the mainland to fish, or transport goods and even sports such as wrestling, which has been practiced in Sudan for thousands of years up to the present (Breasted, 1917; Carroll, 1988; Clapham & Rowley-Conwy, 2007; Lado, 2011; Rumball et al., 2005; Welsby, 2002). This is supported by the study by Van der Merwe et al. (2010) on 19th century South African miners where the cause of spondylolysis observed was attributed to strenuous physical work and high-risk environments.

Traditional agricultural communities, both today and in the past in Nubia and Sudan, are generally involved in repetitive activities that involve strenuous physical activity that puts pressure on the spine such as harvesting crops, weeding, digging, and lifting (Cogbill et al., 1991). These activities could account for the evidence for spondylolysis seen in this study, but when compared with modern athletes or other archaeological populations, the Nubian frequencies were low. It is unlikely that these populations were not involved in intensive repetitive action, as they were rural communities reliant on agriculture. High CPRs of other spinal pathologies seen in these populations such as osteoarthritis (48%), spondylosis (80.3%), and Schmorl's nodes (22.7%) support the view that these populations were engaged in repetitive physical activities (Tipper, 2020). Therefore, it may be the case that the Nubian populations in this study did not inherit a weakness at the pars interarticularis in their spines, possibly as a result of high bone density and bones less predisposed to fracture (Aloia, 2015; Finkelstein, 2002; Tipper, 2020).

Finally, it should be noted that the key limitation faced during this research was the lack of comparable studies. There are few studies on spinal pathology published in the bioarchaeological literature and this is especially the case for ancient Nubia. Additionally, other studies are often of limited use because of the differences in methods used to record and present their data (Tipper, 2022). A third limitation was the limited contextual data for some sites due to inaccessible unpublished reports or because data was not thought important and not collected. This was particularly the case for Semna South where only preliminary reports were published.

6 | CONCLUSION

To conclude, low levels of spondylolysis were observed in the populations in this study, with similar results to other bioarchaeological studies of spondylolysis in Egypt and modern African studies. These low levels could be a result of a low genetic predisposition to spondylolysis or low exposure to potential hazards. Archaeological contextual information can potentially highlight activities that could contribute to the development of spondylolysis, such as building, rowing boats, and agricultural activities, but it is not possible to be specific about which activity/ies caused spondylolysis. Chronologically, the prevalence of spondylolysis was highest in the Medieval period, suggesting an increase in exposure to risk factors resulting in spondylolysis during this period. This could be a result of the increase in political and economic instability during this time period, leading to the deterioration of living conditions and an increase in disease and stress. Higher prevalence rates were also seen for people from sites with harsher environments between the First and Fourth Cataracts (less fertile land, steep riverbanks, and areas of hard granite bedrock), compared with the more fertile and flatter land between the Fourth to Sixth cataracts. However, as an increase in spondylolysis is seen over time, climate change (deteriorating climatic conditions and aridification) might be a causative factor, but more comparative data are needed from other populations from across ancient Nubia before any final conclusions can be made. Although there have been a number of studies on spondylolysis in populations around the world, little has been published on ancient Nubian populations, making the comparison of data difficult. It is hoped that future research can build on the data presented in this study.

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CONFLICT OF INTEREST STATEMENT

None.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in Ethesis Durham University at https://etheses.dur.ac.uk/secure/.

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